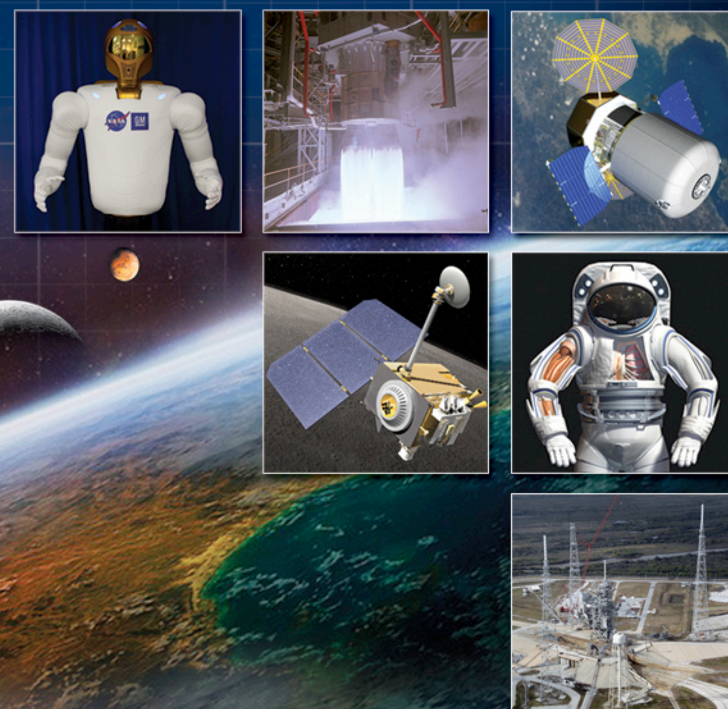
National Aeronautics and Space Administration

A New Space Enterprise of Exploration



Flagship Technology Demonstrations (FTD)
AR&D Vehicle (ARDV) Overview

Presented at NASA's Exploration Enterprise Workshop

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Tim Crain/NASA-JSC
Jack Brazzel/NASA-JSC

5/25/2010

Disclaimer

- This chart set was presented on May 26, 2010 at the NASA Exploration Enterprise Workshop held in Galveston, TX. The purpose of this workshop was to present NASA's initial plans for the potential programs announced in the FY2011 Budget Request to industry, academia, and other NASA colleagues. Engaging outside organizations allows NASA to make informed decisions as program objectives and expectations are established.

- The following charts represent at "point of departure" which will continue to be refined throughout the summer and the coming years. They capture the results of planning activities as of the May 25, 2010 date, but are in no way meant to represent final plans. In fact, not all proposed missions and investments fit the in budget at this time. They provide a starting point for engagement with outside organizations (international, industry, academia, and other Government Agencies). Any specific launch dates and missions are likely to change to reflect the addition of Orion Emergency Rescue Vehicle, updated priorities, and new information from NASA's space partners.

Purpose and Content of Briefing

- This briefing summarizes the FTD Study Team's work on the Automated/ Autonomous Rendezvous & Docking Vehicle (ARDV) and its role in the FTD missions.
  – AR&D working definition is given in back-up information
- Provides overall context for the RFI and sets the stage for Q&A
  – RFI Link: http://nspires.nasaprs.com/external/solicitations go to # NNH10ZTT003L
- Note: During the FTD study the ARDV was referred to as the "Flagship Service Vehicle (ARDV)". This nomenclature appears in parts of this briefing.
- <u>Briefing Outline:</u>
  I. Overview and Background of FTD and ARDV
  II. Summary of AR&D Vehicle Objectives within FTD and FTD ARDV RFI
  III. Summary of Point of Departure Conceptual Design Work To-Date
  IV. Back-Up Information

Flagship Technology Demonstrations (FTD)

I. Overview and Background of FTD and AR&D Vehicle (ARDV)

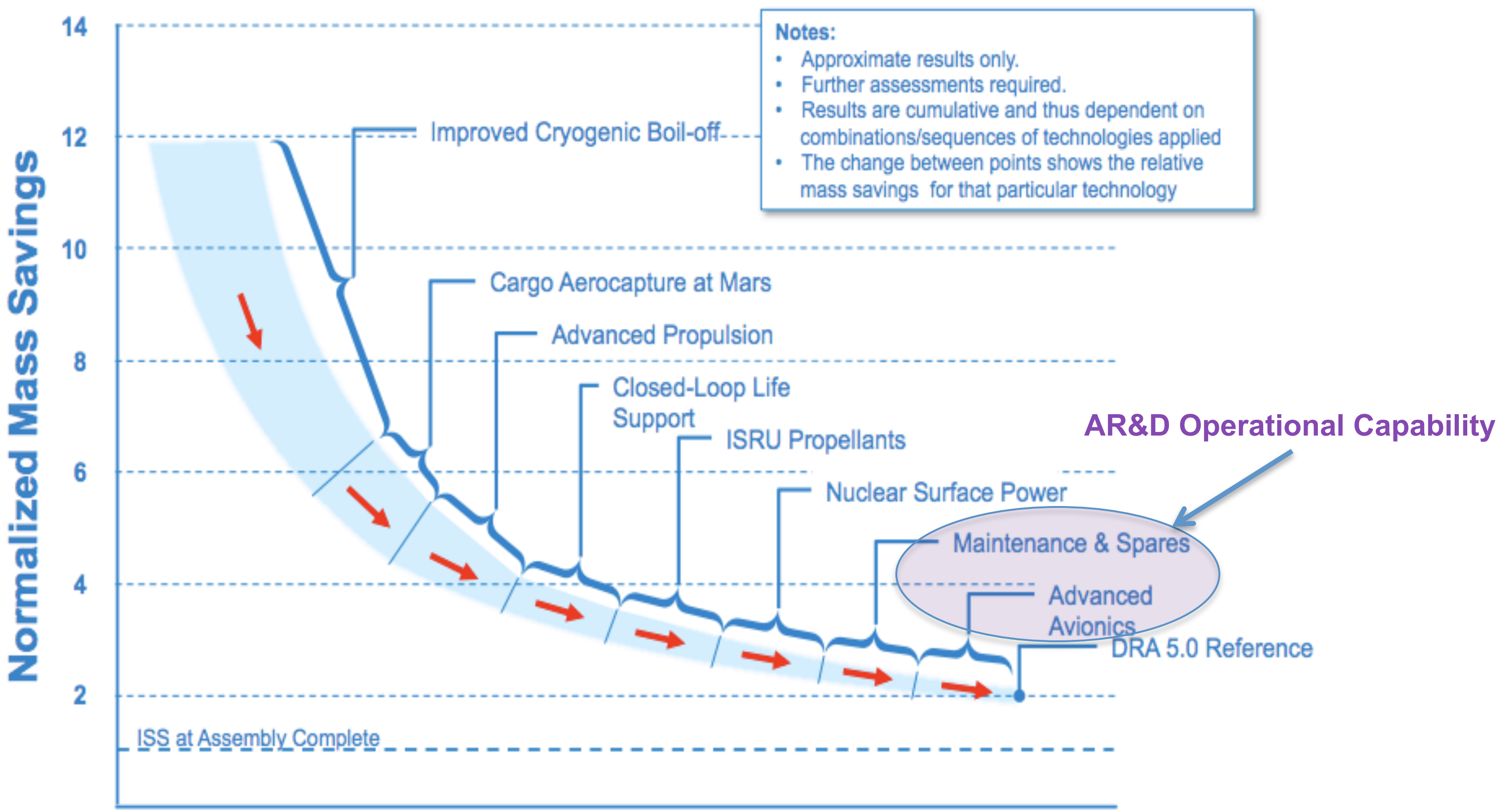
Flagship Technology Demonstrations
FTD Program and AR&D Vehicle Work to-date Overview

- What are Flagship Technology Demonstrations?
  - A planned new NASA Program that demonstrates the technologies needed to reduce the cost and expand the capability of future space exploration activities.
    - They are large scale demonstrations in space of technologies that could be transformational
    - Improves the capability and reduce the cost of future exploration missions
  - General Principles guiding the preliminary selection and implementation of the projects:
    - Costs, from initiation to launch, should range from $400M to $1B each, including launch vehicle
    - Project lifetime no longer than five years (initiation to launch)
    - First in-space demo should be targeted for no later than 2014
    - International, commercial and other government agency partners should be actively pursued as integrated team members where appropriate
    - No single NASA Center should have responsibility for all demos
  - NASA FTD Study Team formed in early February 2010 with members drawn from NASA Centers and HQ. The Team developed:
    - A Preliminary Mission Set based on guidance received and consultations with experts in the technology areas
    - Developed Needs, Goals, and Objectives for the Program and the missions
    - Straw man development schedules and acquisition options
    - Point of departure preliminary mission designs
- ARDV sub-Team lead by GSFC with JSC and MSFC members
    - GSFC- spacecraft and mission design
    - JSC & MSFC- AR&D expertise

Flagship Technology Demonstrations

FTD Program Overview-Prime Motivation for Program

FTD targets technologies that once mastered dramatically increase our human exploration capability.



Flagship Technology Demonstrations

FTD Preliminary Missions Definition & Integration of AR&D

FTD Launches/ Missions Key Technologies	FTD-1 SEP Mission*	FTD-2 Propellant Storage Mission*	FTD-3 Inflatable Mission*	FTD-4 AeroCapture EDL Mission
Propellant Transfer and Storage		X		
Lightweight/ Inflatable Modules			X	X
AR&D	X	X	X	
Closed Loop Life Support			X	
Aero-capture and EDL				X
Advanced Space Propulsion	X			
* Flagship Service Vehicle is a common element needed across multiple FTD missions, but is not a separate mission	* ARDV-Lite AR&D Vehicle	* ARDV AR&D Vehicle	* ARDV AR&D Vehicle	

Advanced Solar Electric Propulsion: This will involve concepts for advanced high-energy, in-space propulsion systems which will serve to demonstrate building blocks to even higher energy systems to support deep-space human exploration (crew and cargo) and eventually reduce travel time between Earth's orbit and future destinations for human activity.

In-Orbit Propellant Transfer and Storage: The capability to transfer and store propellant—particularly cryogenic propellants—in orbit can significantly increase the Nation's ability to conduct complex and extended exploration missions beyond Earth's orbit. It could also potentially be used to extend the lifetime of future government and commercial spacecraft in Earth orbit.

Lightweight/Inflatable Modules: Inflatable modules can be larger, lighter, and potentially less expensive for future use than the rigid modules currently used by the International Space Station (ISS). NASA will pursue a demonstration of lightweight/inflatable modules for eventual in-space habitation, transportation, or even surface habitation needs.

Automated/Autonomous Rendezvous and Docking: The ability of two spacecraft to rendezvous, operating independently from human controllers and without other back-up, requires advances in sensors, software, and real-time on-orbit positioning and flight control, among other challenges. This technology is critical to the ultimate success of capabilities such as in-orbit propellant storage and refueling, and complex operations in assembling mission components for challenging destinations.

Closed–loop life support system demonstration at the ISS: This would validate the feasibility of human survival beyond Earth based on recycled materials with minimal logistics supply.

Aerocapture, and/or entry, descent and landing (EDL) technology: This involves the development and demonstration of systems technologies for: precision landing of payloads on "high-g" and "low-g" planetary bodies; returning humans or collected samples to Earth; and enabling orbital insertion in various atmospheric conditions.

Flagship Technology Demonstrations

FTD Program Overview-Study Team Membership

The FTD) Core Study Team included:

- **Mike Conley (JSC-EV111), Team Lead**
- **Linda Bromley (JSC-EA411)**
- **Helen Grant (HQ-BK000)**
- **Keith Hefner (MSFC-VP22)**
- **Renee Leck (HQ-BI000)**
- **Benjamin Neumann (HQ-BL000)**
- **Bernard Seery (GSFC-1000)**
- **Kim Ulrich (JSC-ON111)**
- **Mike Weiss (GSFC-4550)**
- **Jim Lynch (HQ-BJ000, Freedom)**
- **Michael Patterson (GRC-RP00), FTD-1 Lead**
- **Stephan Davis (MSFC-JP60), FTD-2 Lead**
- **Tony Sang (JSC-OB211), FTD-3 Lead**
- **Pat Troutman (LaRC-E402), FTD-4 Lead**
- **Craig Tooley (GSFC-4510), ARDV Lead**

The FTD ARDV/AR&D Sub-Team included:

- **Craig Tooley/NASA-GSFC – ARDV/AR&D Lead**
- **Charles Baker/NASA-GSFC-Systems & Thermal**
- **David Peters/NASA-GSFC-Mechanical**
- **Jeff Stewart/NASA-GSFC-Mechanical**
- **Ron Zellar/NASA-GSFC- Systems**
- **Charles Zakrzwski/NASA-GSFC-Propulsion**
- **Bo Naasz/NASA-GSFC-GN&C/AR&D**
- **Glenn Rakow/NASA-GSFC-Avionics**
- **Jonathon Wilmot/NASA-GSFC- Avionics Software**
- **Adan Rodriguez-Arroy/NASA-GSFC-Communications**
- **Tim Crain/NASA-JSC-AR&D**
- **Jack Brazzel/NASA-JSC-AR&D**
- **Jeremy Hart/NASA-JSC-AR&D**
- **Tom Bryan/NASA-MSFC-AR&D**
- **Richard Howard/NASA-MSFC-AR&D**
- **David Di Pietro/NASA-GSFC Lead Mission Design Lab (MDL) & MDL Engineering Support Staff**

(All FTD missions had Sub-Teams, only ARDV shown here)

Flagship Technology Demonstrations AR&D Vehicle (ARDV) Overview

II. Summary of ARDV Objectives within FTD and FTD ARDV RFI

Automated/Autonomous Rendezvous & Docking Vehicle (ARDV) FTD *Overview Quad-Chart*

Mission Description:

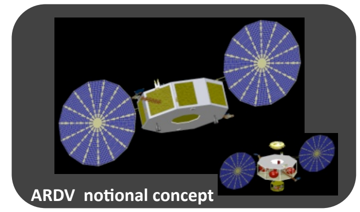
- Primary platform for AR&D demos on missions (a primary objective on 3 of 4 missions)
- Multi-purpose vehicle used across Flagship Technology Demonstration (FTD) Missions
  - De-orbit/dispose of completed missions
  - Carrier, with services, for ETDD & OCT demonstration missions as secondary payloads
  - $\triangle$V capability scalable for mission
  - Option for reusable architecture with on-orbit refueling
  - Delivers FTD Missions to destinations such as ISS

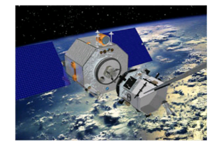

OMV circa 1986


ATV

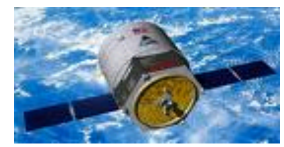

HTV


HRSDM


ARDV notional concept


Orbital Express


DragonLab


Cygnus

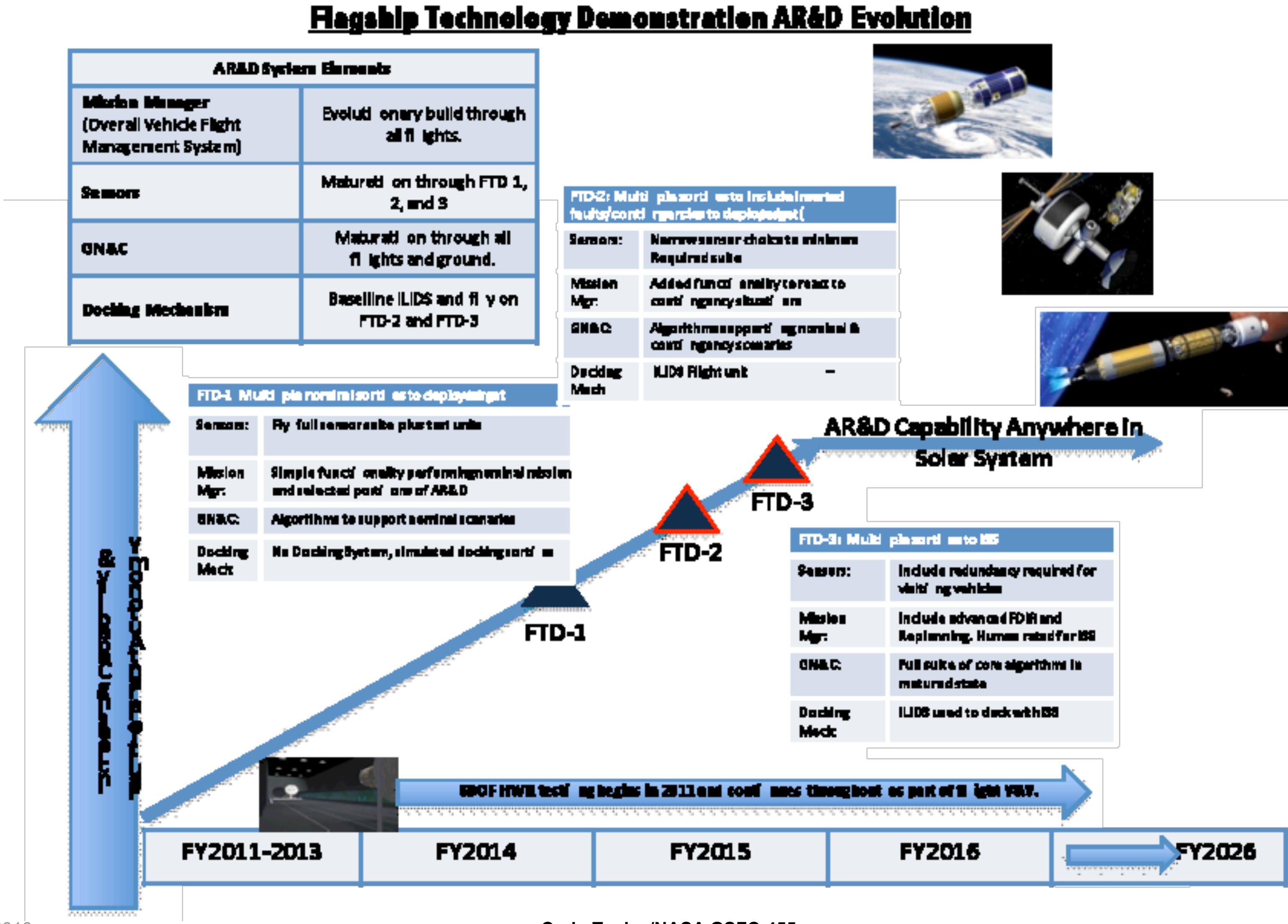
Goals and Objectives:

- Evolutionary flight testing of integrated AR&D systems.
  - Sensor suites
  - Mission Manager System
  - Two-way communication including ranging
- Provide in-orbit transportation and delivery to FTD missions.
- Provide robust ISS rated spacecraft system elements for later FTD missions.
- Build upon past experience and lessons learned in the AR&D arena

Partnerships:
Potential partners include Internationals, industry, and commercial partners

Timeframe and ROM Resources:
Developed as part of 1st FTD mission with additional builds for subsequent missions that require it.

FTD ARDV AR&D Capability Evolution Overview



FTD AR&D Vehicle (ARDV)
Goals and Objectives and FTD Technology Allocation*

(1 of 2)

Mission or Technology Goals	Mission or Technology Objectives	AR&D Demonstration Vehicle MOE for FTD Mission 1 (SEP)	AR&D Demonstration Vehicle MOE for FTD Mission 2 (Depot)	AR&D Demonstration Vehicle MOE for FTD Mission 3 (Inflatable)
<u>Mission Goal 1:</u> Provide capability for a common servicing vehicle for flagship missions	**Objective 1-1:** Demonstrate Automate Rendezvous, proximity operations and docking	Successfully demonstrate automated near-field rendezvous, proximity operations, and simulated docking operations. SEP mission AR&D Demonstration Vehicle design architecture (computational hardware and Software) is common to planned FTD-2 and FTD-3 missions. Demonstrates automated vehicle safing and recovery from simple communication faults. System designs are extensible	Demonstrate robust ability to perform automated and autonomous rendezvous, (both near and far-field), proximity operations, and docking. Demonstrate all nominal contingency operations required for FTD-3 Successfully demonstrate use of IDS docking system with CBA on Depot.	Successfully rendezvous with ISS while carrying Inflatable payload Successfully perform the proximity operations near ISS necessary to berth and/ or dock the Inflatable payload. Successfully perform the proximity operations near ISS necessary to dock the AR&D Demonstration Vehicle to the ISS.
	Objective 1-2: Provide orbital maneuvering capability	Execute perigee raising maneuver for SEP/ AR&D Demonstration Vehicle stack. Execute maneuvers necessary for AR&D demonstrations	Execute maneuvers necessary for AR&D demonstrations	Execute maneuvers required for rendezvous, berthing and docking operations with ISS.

FTD AR&D Vehicle (ARDV)
Goals and Objectives and FTD Technology Allocation*
(2 of 2)

Mission or Technology Goals	Mission or Technology Objectives	AR&D Demonstration Vehicle MOE for FTD Mission1 (SEP)	AR&D Demonstration Vehicle MOE for FTD Mission 2 (Depot)	AR&D Demonstration Vehicle MOE for FTD Mission 3 (Inflatable)
Mission Goal 1: Provide capability for a common servicing vehicle for flagship missions	**Objective 1-3**: Host equipment necessary for specific FTD missions	None defined.	Host Cryo Transfer Kit on AR&D Demonstration Vehicle for demonstration on inter-vehicular transfer.	None defined
	Objective 1-4: Provide in-orbit support for passive companion payloads across the separable interface	None defined	None defined	Provide heater power and temperature telemetry services to Inflatable during transport to ISS
	Objective 1-5: Provide the capability of operation in both LEO and GEO orbit environments	Demonstrate vehicle operation in GEO	Demonstrate vehicle operation in LEO	Demonstrate vehicle operation in LEO (ISS)

* Excerpted from ESMD Program Resources and Guidance (PRG) 2011 PPBE, FTD Section

FTD AR&D Vehicle (ARDV) RFI – Vehicle Bus

- **NASA is seeking information, ranging from components to full systems, relevant to the development of an ARDV spacecraft that has the characteristics below:**
  - Vehicle can be stacked with a FTD payload and launched on a medium sized ELV.
  - Vehicle serves as a demonstration test-bed for Automated Rendezvous and Docking systems and capabilities. It is envisioned that this vehicle will demonstrate AR&D capabilities through the performance of AR&D sorties on multiple Flagship missions using the co-launched Flagship payload as the passive target vehicle and the ARDV performing as the active vehicle.
  - Vehicle is capable of transporting an FTD payload from an initial ELV ISS co-elliptical orbit to the ISS and both docking and berthing the payload with ISS.
  - Vehicle can be developed and qualified for the first FTD mission to be launched in 2014 and the second and third FTD missions planned to launch in 2015.
  - The docking system used for FTD AR&D demonstrations will be a production version of NASA Low Impact Docking System (iLIDS) which meets the international Docking System Standard currently being developed. An overview of the iLIDS is provided in the reference library associated with this RFI.
  - During NASA's preliminary study of the FTD and missions a conceptual design for an ARDV was developed to examine the feasibility of building the ARDV and to serve as a point of departure for its development. The notional requirements used to execute the design study are provided in the reference library. These are provided for reference only and should not be construed as specific requirements, specification or direction for an ARDV design.

FTD AR&D Vehicle (ARDV) RFI – AR&D System
(1 of 2)

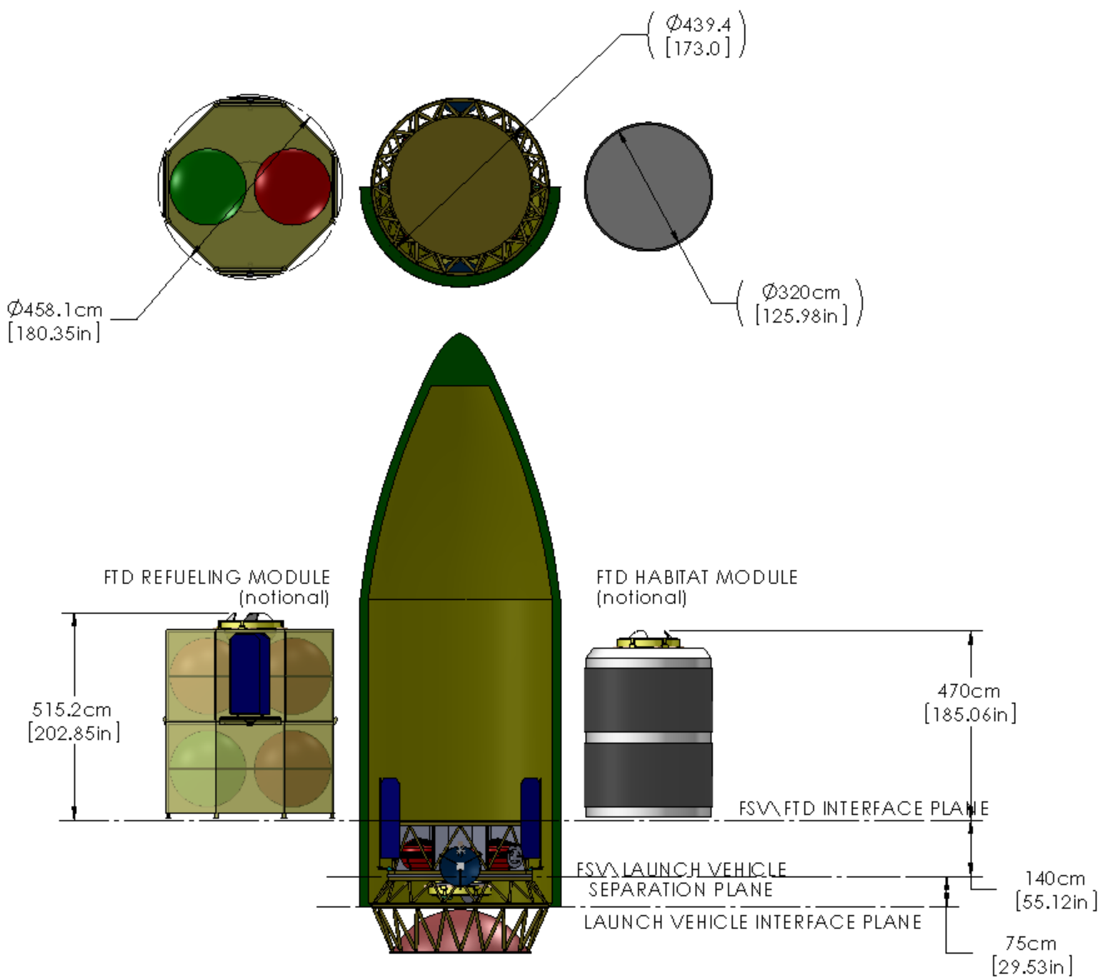
- **The AR&D elements that NASA envisions are necessary for the planned FTD demonstrations of AR&D and requests information and ideas about are:**
  - **Mission Manager:** The desired attributes of a mission manager include:
    - » Configurable design accommodating of greater or lesser automation and autonomy as the mission requirements dictate.
    - » Mission management extensible to multiple DRMs with common software core.
    - » Amenable to meaningful and efficient re-use across multiple missions.
    - » Application compatible with high TRL space computation resources
  - **Inter-vehicle RF communication systems:** These systems will enable communication between space vehicles and perform range and range-rate measurements that yield information that will be used for autonomous relative navigation. The ability to determine bearing information between the two (2) vehicles is also potentially desirable. Specifically, the following attributes are desirable:
    - » Long distance RF range/rate standard production radio, ranges 1 km to 300+km scalable by power
    - » Omni direction operation during prox ops
    - » Space qualified or feasible course for space qualification
  - **Laser Sensors:** The desired attributes of laser sensors to be used for relative navigation include:
    - » Proximity operations sensor for non-cooperative vehicles from > 3 km to < 1m on docking axis, lighting independence
    - » Docking sensor sufficient for IDSS capture envelope, lighting independence
    - » Dissimilar/overlapping sensing for FDIR and contingencies
    - » Mass and power less than 15 kg and 50 W for proximity operations sensor
    - » Space qualified or feasible course for space qualification

FTD AR&D Vehicle (ARDV) RFI – AR&D System
(2 of 2)

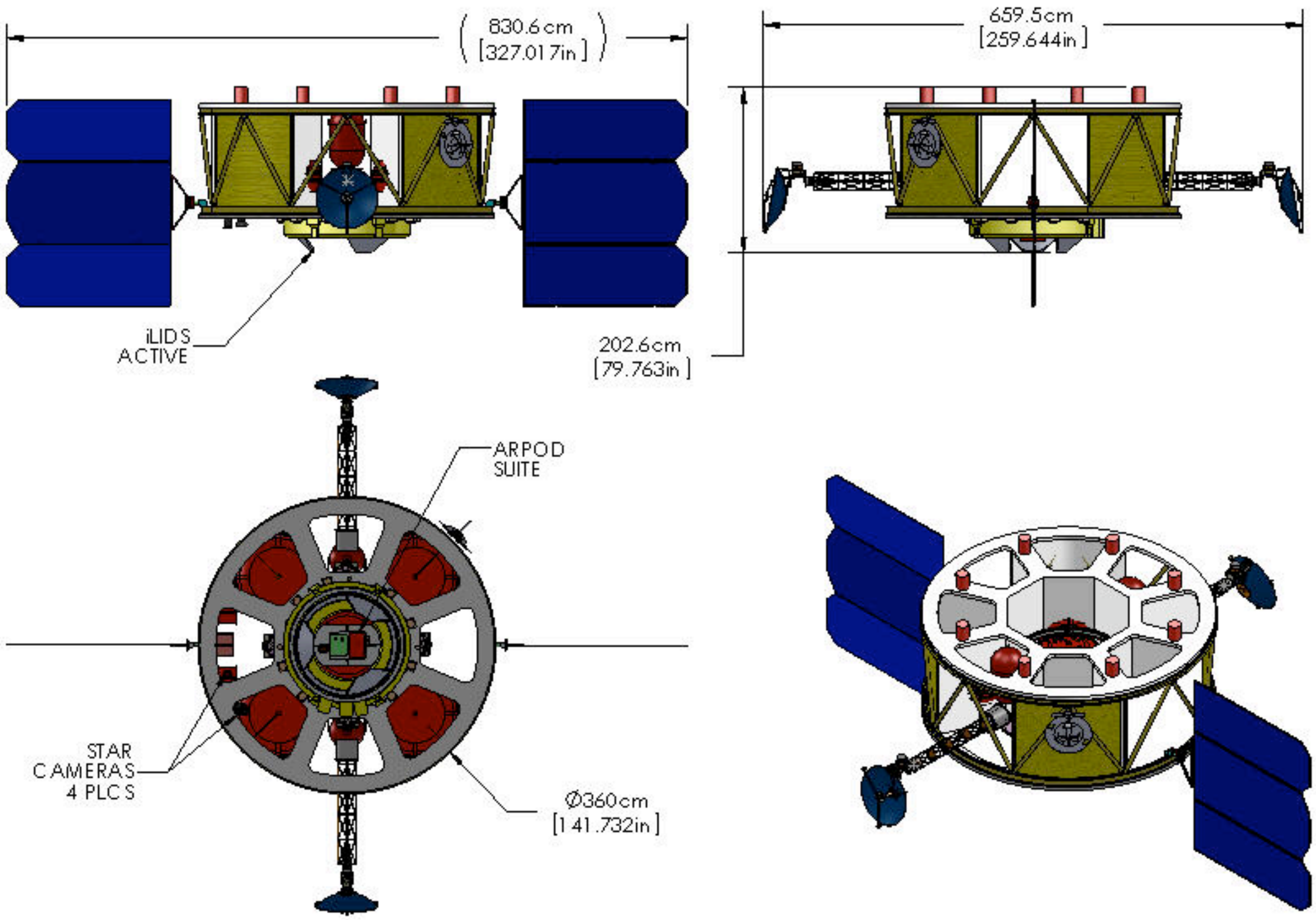
- **The AR&D elements that NASA envisions are necessary for the planned FTD demonstrations of AR&D and requests information and ideas about are:**
  - **Natural Feature Image Recognition (NFIR) Implementations:** The desired attributes of NFIR systems to be used for relative navigation include:
    - Robustness to lighting conditions
    - Experience with optical and IR spectrum features
    - Robustness from model deviation from truth
    - Application compatible with high TRL space computation resources
    - Camera/optics technology
  - **Advanced Vision Processing hardware and software:** The Vision Processing Unit (VPU) will enable the ability to process images for relative navigation information as well as host other important GN&C software functions. It is envisioned as a stand-alone electronics unit that interfaces the AR&D sensor suite to the spacecraft bus main computer(s).
  - **Scalability:** The mission requirements for vehicles to perform AR&D will drive the appropriate level of automation, especially for crewed vehicles. So a desired attribute for the AR&D system will be the ability to scale the level of automation or reconfigure to accommodate more or less human interaction. In addition, the system should allow evolutionary incorporation of automation capabilities.

III. Summary of Conceptual Design Work To-Date

ARDV FTD Preliminary Launch Configurations



ARDV-ARDV Current Baseline Conceptual Configuration
Mono-Propellant w/iLIDS docking System



Flagship Technology Demonstrations
ARDV Status Summary & Overview

ARDV-FTD Design Summary-Mono-Propellant w/iLIDS Docking System

Additional details in back-up

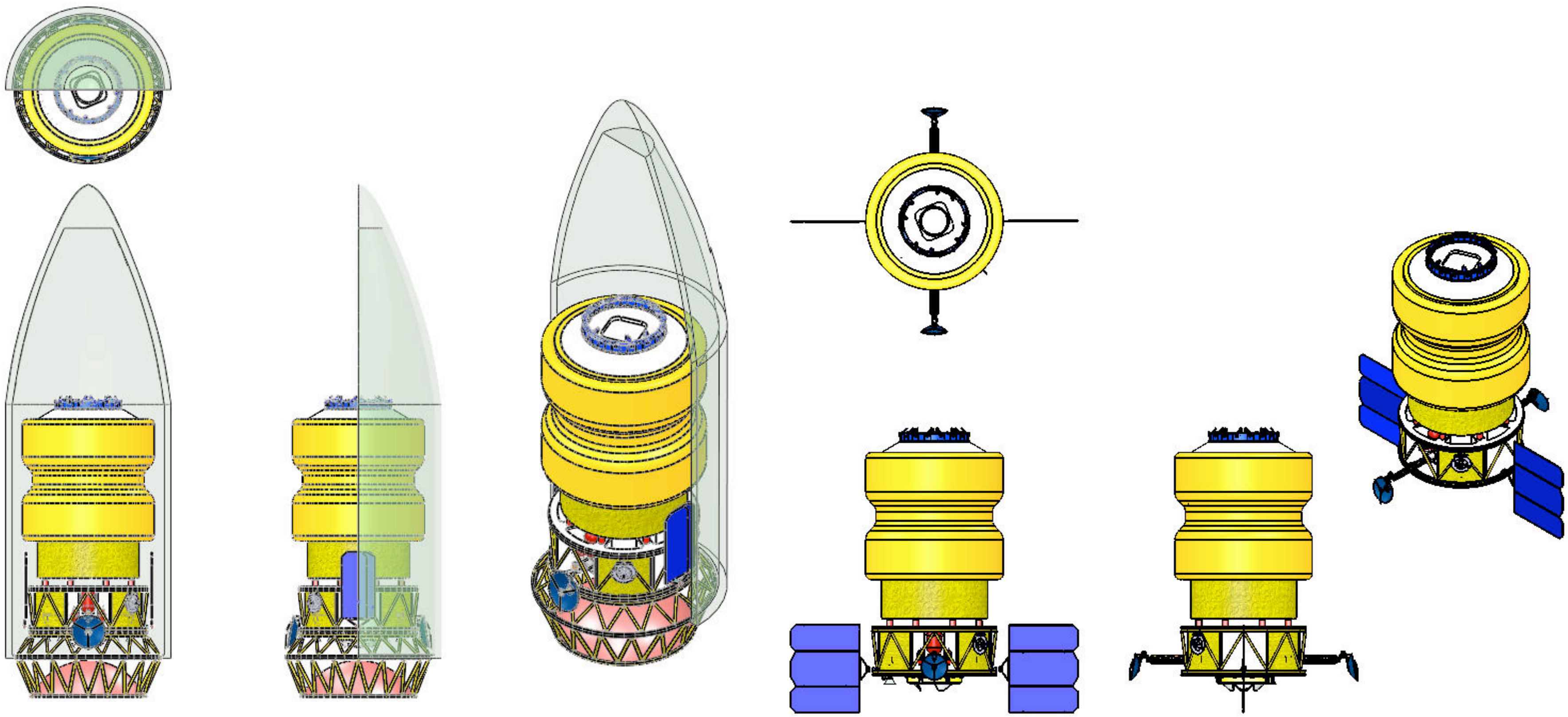
- **System Key Aspects:**
  - Single design to meet FTD-2 (Depot) and FTD-2 (Inflat. Hab.) mission requirements
  - Design must also be GEO operationally capable
  - Class B/1-FT design
  - 2 FT for FS when in ISS AE
  - 5 year life in LEO
  - 2 year life in GEO
  - Fine pointing capability as free-flyer for secondary payloads
  - Compatible with medium class EELVs

- **Key Design Drivers**
  - AR&D Communication (5Mbs live when docking)
  - Assumed attitude constraints drive multiple articulated HGAs and SAs
  - Five year life in LEO requires drag make-up
  - Stipulated large fuel capacity
  - ISS manned safety requirements
  - ➢ *Lead to a very capable but somewhat complex, heavy vehicle that still must be optimized.*

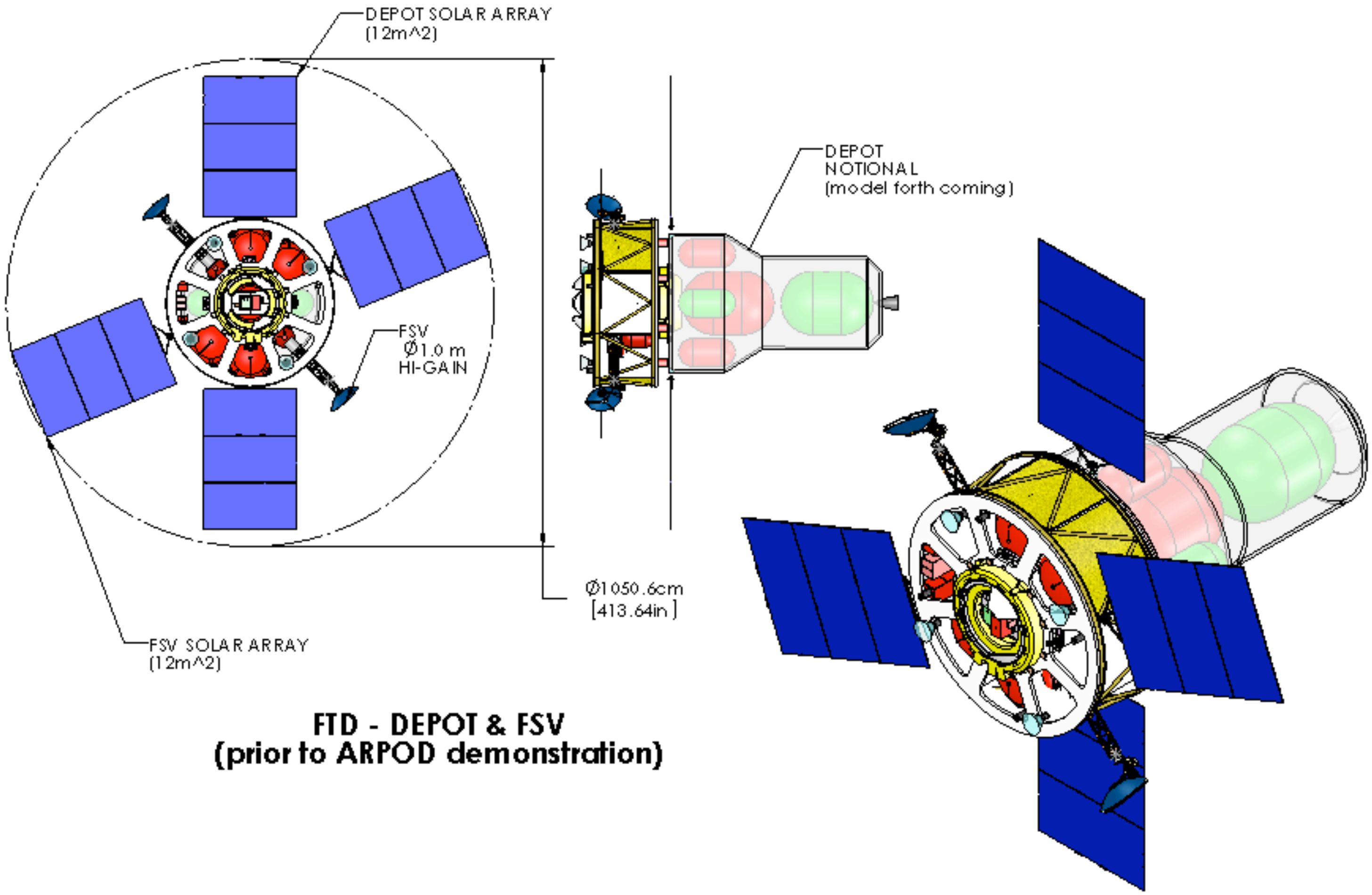
FSV-FTD Spacecraft MEL Summary
Sized for 10000 kg Primary Payload

Subsystem	LRO (comparison)	LRO Percentages	FSV CBE [kg]	FSV Percentages
FSV-FTD Spacecraft	1015		1525	
ACS	61	6.0%	42	3%
C&DH	23	2.3%	81	5%
Harness	71	7.0%	71	5%
Power	170	16.7%	201	13%
RF Comm	73	7.2%	34	2%
Structure and Mechanisms	317	31.2%	562	37%
Thermal	86	8.5%	57	4%
Mono-Prop Propulsion (dry)	121	11.9%	248	16%
AR&D Suite	93	9.2%	49	3%
ILIDS Docking			181	12%
Dry Mass	1015		1525	
Additional Payload				
Propellant Mass	897		2163	
Wet Mass	1912		3688	

FTD Inflatable ISS Habitat Mission Concept

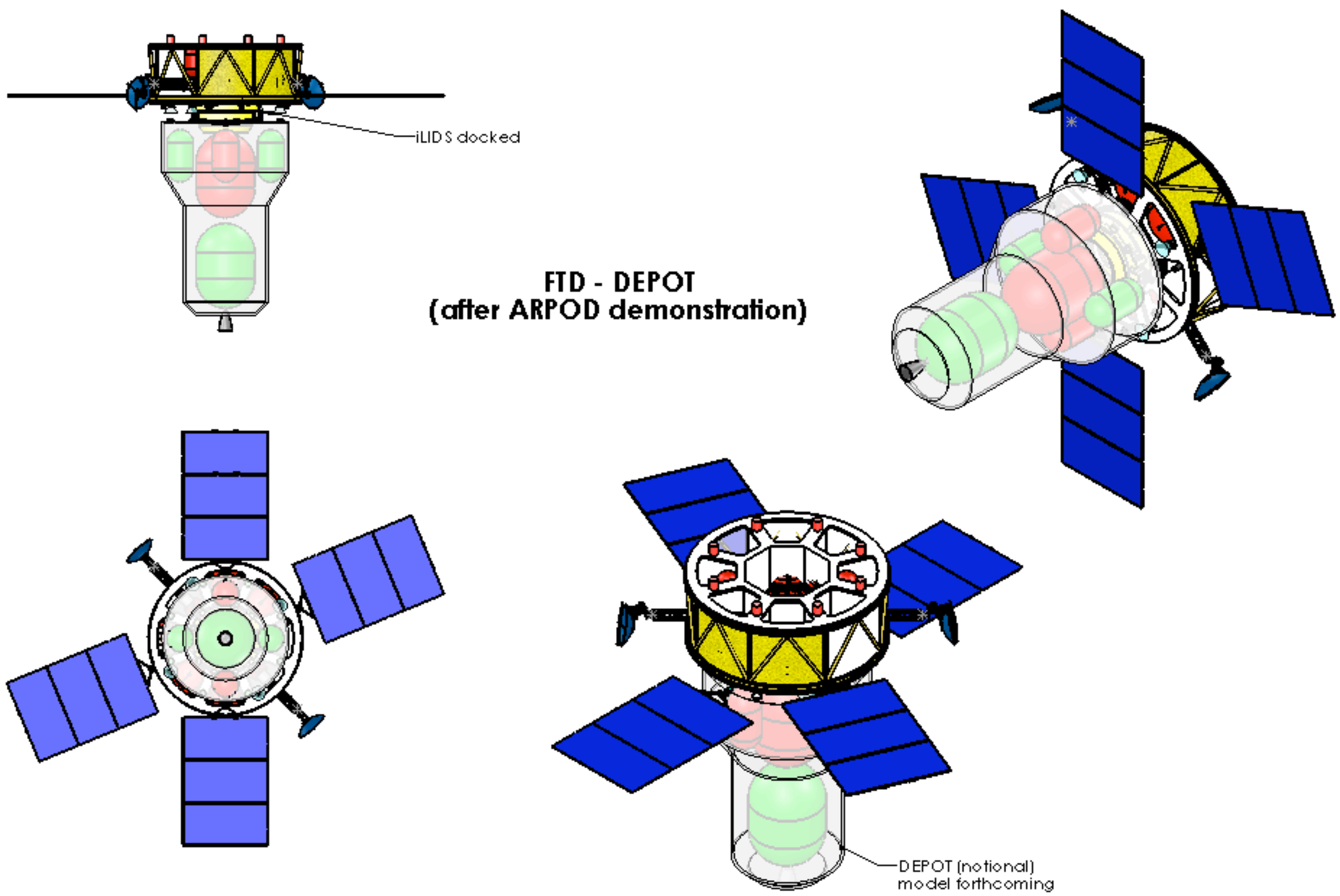


FTD Cryogenic Propellant Depot Mission Concept

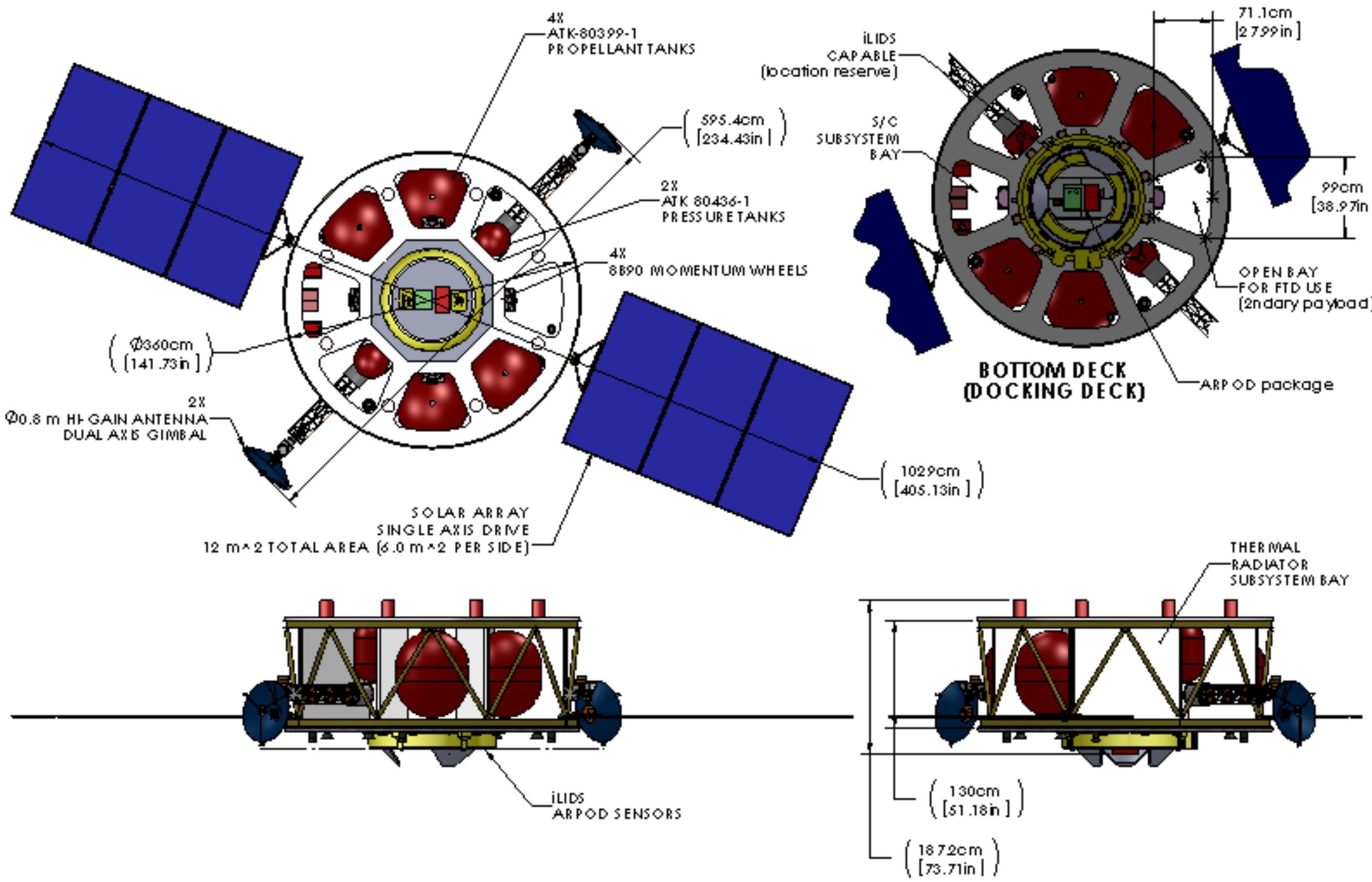


FTD - DEPOT & FSV
(prior to ARPOD demonstration)

FTD Cryogenic Propellant Depot Mission Concept



ARDV-Tug Current Conceptual Configuration
Bi-Propellant w/o iLIDS Docking System



Flagship Technology Demonstrations
ARDV-Tug Concept (for ISS, applicable to FTD)

ARDV-Tug Design Summary-Bi-Propellant w/o iLIDS Docking System

Additional details in back-up

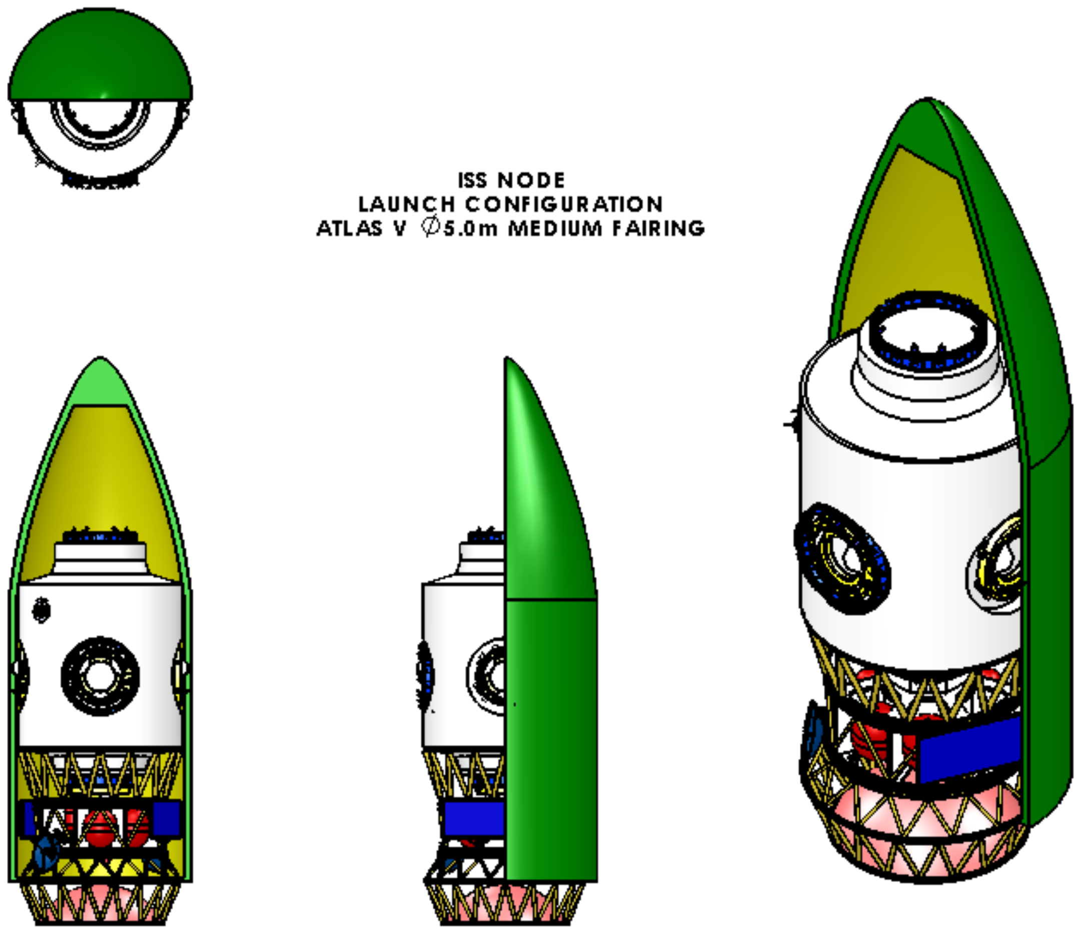
- **System Key Aspects:**
  - Version of ARDV-FTD tailored for ISS Tug duty
  - Class B/1-FT design
  - 2 FT for FS when in ISS AE
  - Fine pointing capability as free-flyer for secondary payloads
  - Design must also be GEO operationally capable
  - Compatible with medium class EELVs
  - Large excess propellant capacity available for secondary mission objectives
    - » 750 kg required for Docking Node Delivery
    - » 1600 kg extra capacity/capability

- **Key Design Drivers**
  - AR&D Communication (5Mbs live when docking)
  - Assumed attitude constraints drive multiple articulated HGAs and SAs
  - Stipulated large fuel capacity
  - ISS manned safety requirements

FSV-Tug Spacecraft MEL Summary
Sized for 10000 kg Primary Payload

Subsystem	LRO (comparison)	LRO Percentages	FSV CBE [kg]	FSV Percentages
FSV-Tug Spacecraft	1015		1232	
ACS	61	6.0%	42	3%
C&DH	23	2.3%	81	7%
Harness	71	7.0%	71	6%
Power	170	16.7%	201	16%
S-Band Comm System	73	7.2%	34	3%
Structure and Mechanisms	317	31.2%	543	44%
Thermal	86	8.5%	57	5%
Bi-Prop Propulsion (dry)	121	11.9%	155	13%
AR&D Suite	93	9.2%	49	4%
ILIDS Docking				0%
Dry Mass	1015		1232	
Additional Payload				
Propellant Mass (Max Load)	897		2350	
Wet Mass	1912		3582	

ARDV-Tug w/ ISS Docking Node Preliminary Launch Configuration



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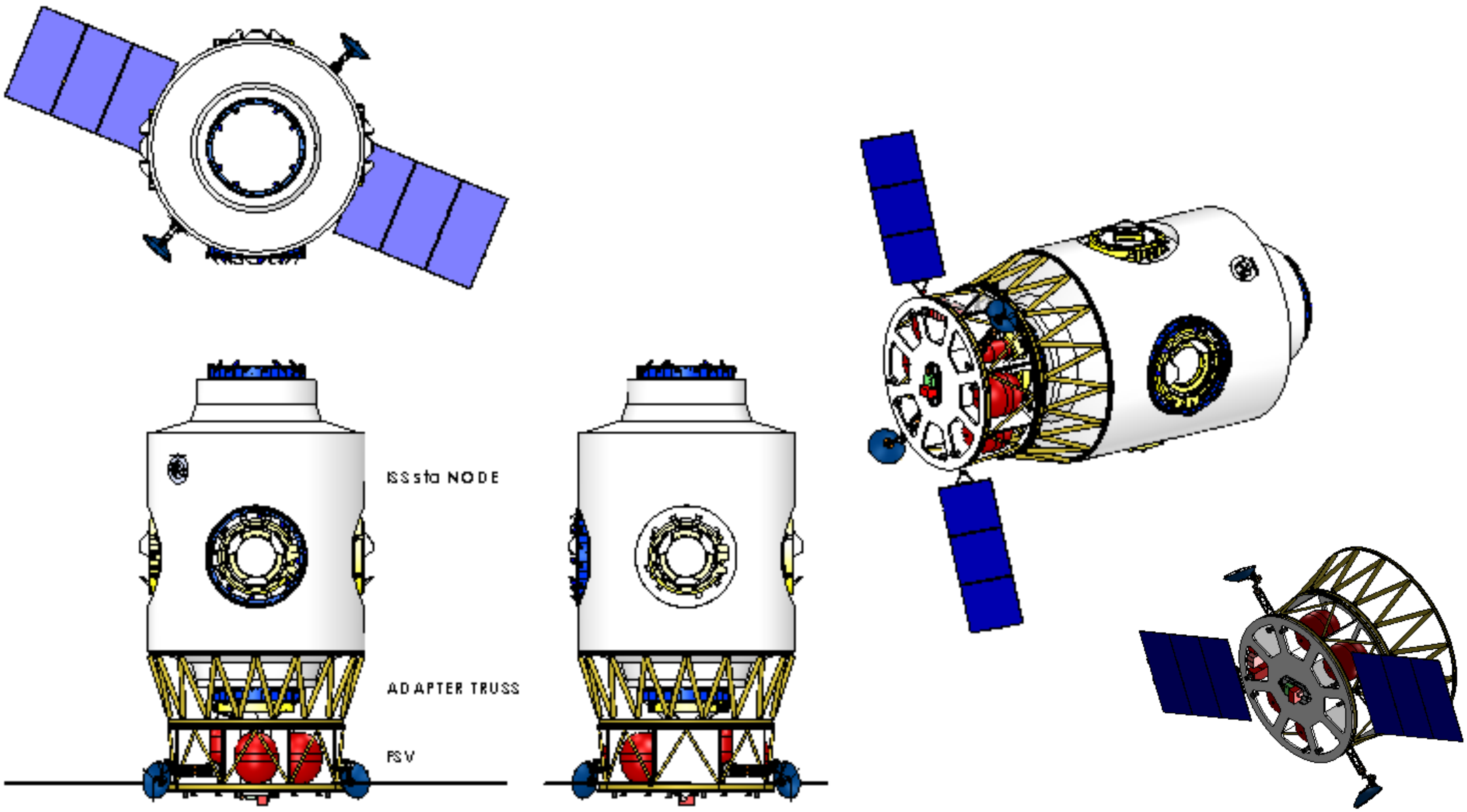
Flagship Technology Demonstrations
ARDV-Tug Concept (for ISS)

ARDV-Tug w/ ISS Docking Node Preliminary On-Orbit Configuration



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Flagship Technology Demonstrations
ARDV Sub-Team Lead

Craig Tooley/NASA-GSFC Flight Projects Directorate

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IV. Back-up Information

- AR&D Definition
- Summary of ARDV Subsystem Designs
- ARDV-Lite Concept for FTD-1/SEP Mission

FTD AR&D Definition

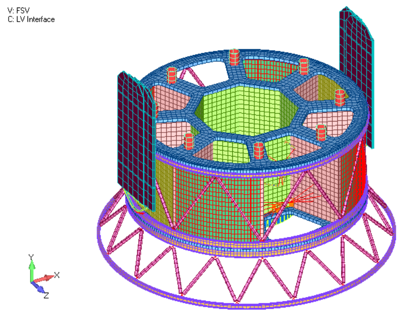
- **AR&D Definition:** AR&D is the autonomous and/or automated execution of the rendezvous and docking phase of flight, including the following segments:
  - 1) Far-field rendezvous of two spacecraft beginning at orbit insertion. This segment is characterized by infrequent relatively large maneuvers to place the chaser vehicle in phasing orbits to catch up to the target vehicle at a specified time in the future. Relative navigation is typically accomplished by differencing the chaser and target vehicle inertial states
  - 2) Near-field rendezvous begins when relative navigation sensors are employed to improve the relative navigation accuracy starting several hundred kilometers in range. This phase requires the chaser vehicle to point relative navigation sensors toward the target vehicle.
  - 3) Proximity operations (6 DOF maneuvering/station-keeping) typically begins when the chaser vehicle is within a few kilometers of the target vehicle. This segment is characterized by frequent thruster firings to maintain a more precise trajectory as the chaser vehicle closes to close proximity of the docking port.
  - 4) Docking is the final segment when the two spacecraft make contact to engage the docking mechanisms for successful capture.

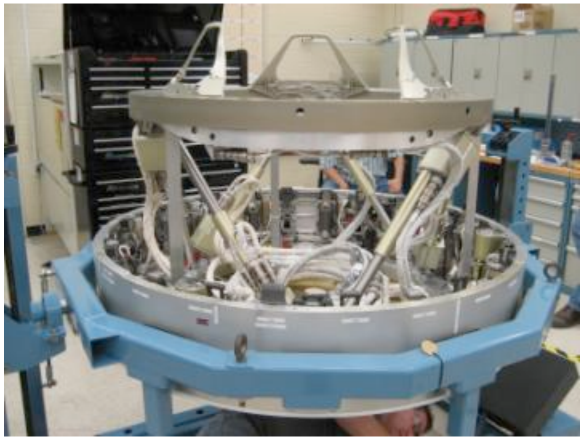
- **Automated and Autonomous Definition:** Automated Rendezvous and Docking (AR&D) encompasses a range of capabilities required to dock two (2) space vehicles without crew piloting.

  - **Automated** (automation) = human vs. computer: Control or execution of a system or process without human intervention or commanding. Function performed via onboard and/or ground software interaction.
  - **Autonomous** (autonomy) = ground vs. onboard: Capable of operating independent of external communication, commands or control (i.e. commands from mission control on Earth). Can involve crew and software in nominal and contingency operations.
  - The level of automation or autonomy is the split between onboard crew, onboard flight computer, and humans on the ground. This is typically a range instead of strictly human/computer or ground/onboard with levels varying greatly based on the application. For envisioned future human exploration endeavors this entire range will be required.

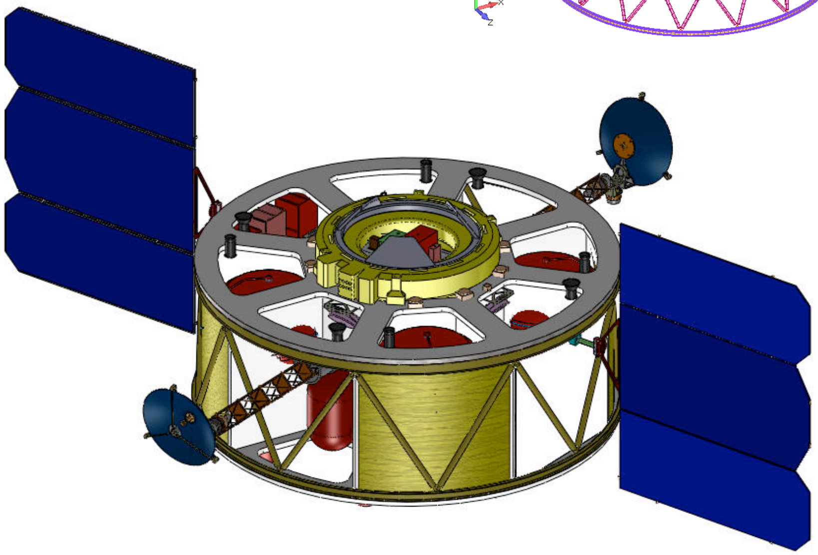
ARDV Design Summary continued

- **Structure & Mechanisms:**
  - Aluminum Decks & Composite tube primary structure. Internal structure Al core/Composite Facesheet panels.
  - One bay and deck space above reserved for FTD equipment.
  - iLIDS Docking System (active side)
  - Pair of deployed HG antennas with 2-axis gimbals
  - Pair of deployed Solar Arrays with 1 axis gimbals
  - Separation system for FTD Companion Payload



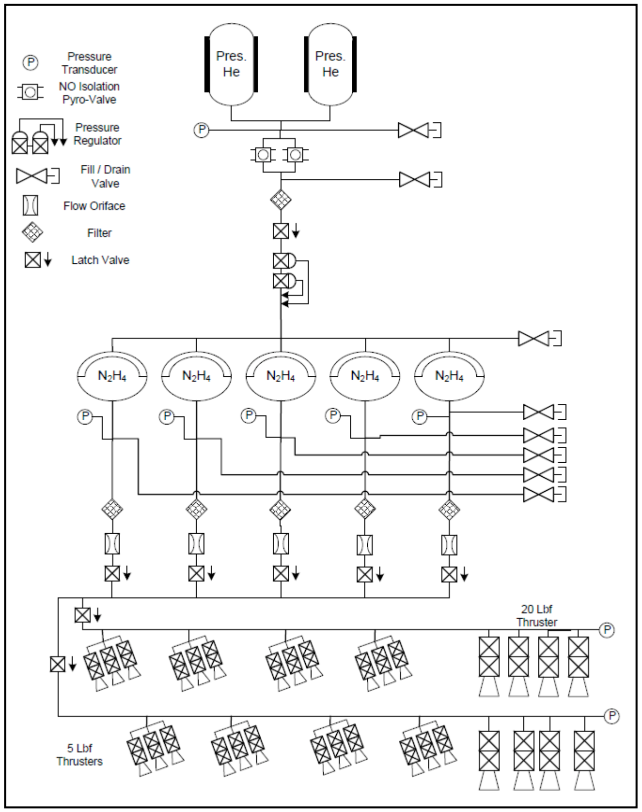


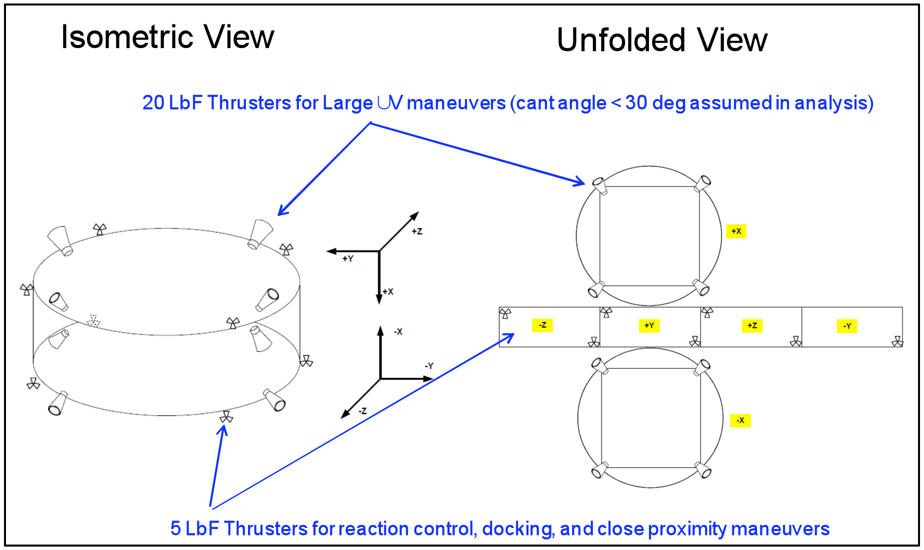
iLIDS



ARDV Design Summary continued

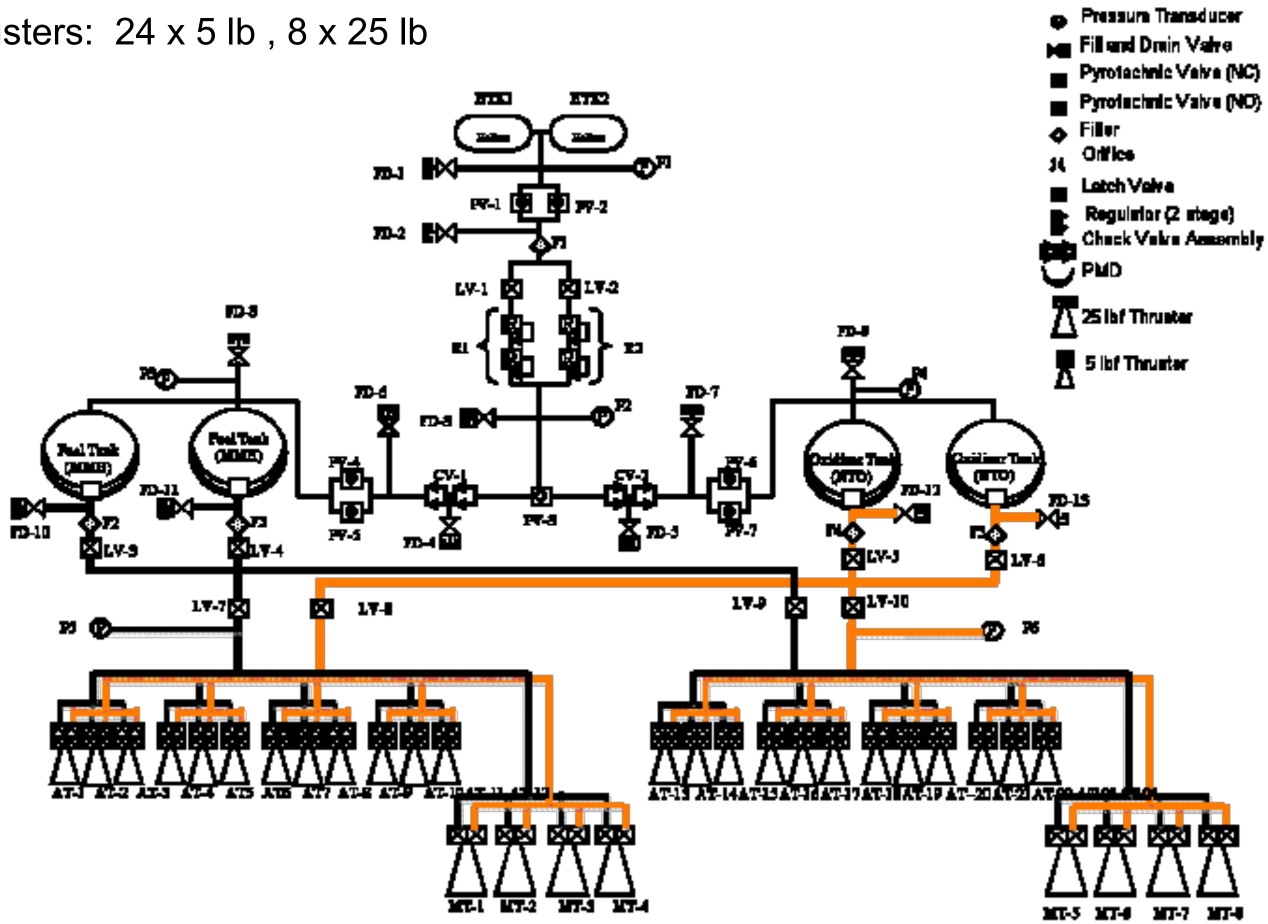
- **Propulsion Option 1:** Monopropellant (N_2H_4) pressure regulated design based on LRO
  - 5 diaphragm tanks + 2 COPV Pressurant tanks (2100 kg fuel capacity)
  - 32 thrusters: 24 x 5 lb , 8 x 20 lb





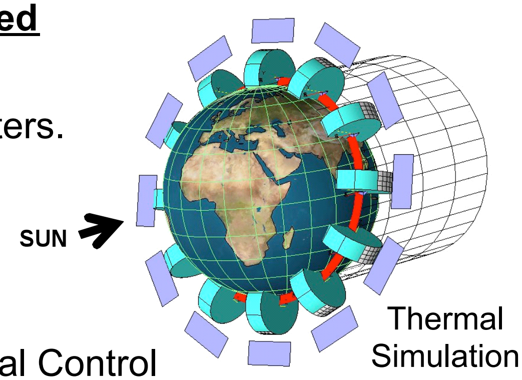
ARDV Design Summary continued

- **Propulsion Option 2:** Bi-propellant (NTO/MMH) pressure regulated design based on SDO
  - 4 PMD tanks + 2 COPV Pressurant tanks (2350 kg propellant capacity)
  - 32 thrusters: 24 x 5 lb , 8 x 25 lb

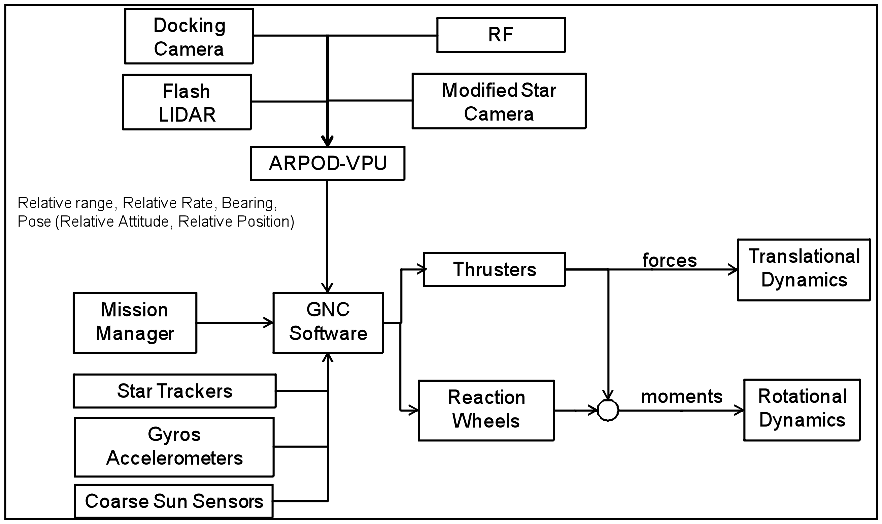


ARDV Design Summary continued

- **Thermal**: Traditional passive design with MLI, radiators and heaters.
  - Radiators sized/placed to fly either earth or anti-earth facing
  - Radiator coatings unique to either LEO or GEO.



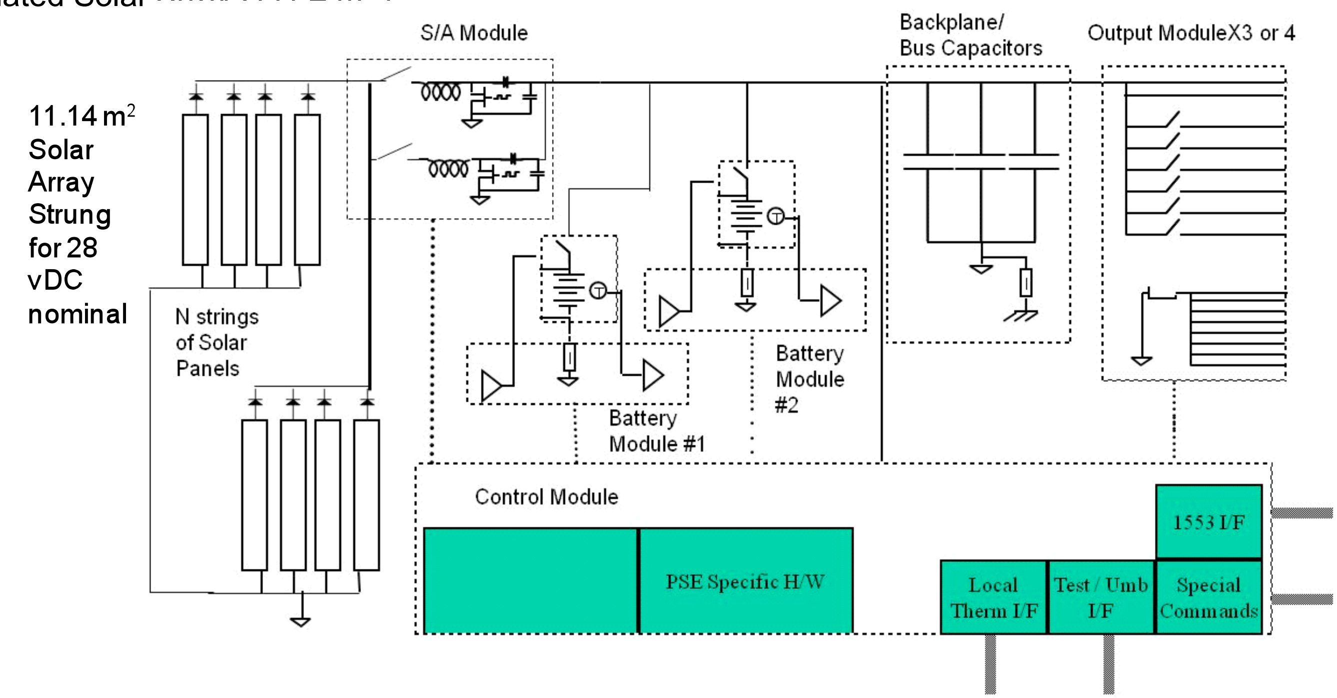
- **Attitude Control System:** Provides Attitude, Thruster and Gimbal Control
  - ACS/GNC software hosted on main computer
  - Two Star trackers (shared with ARPOD suite)
  - Inertial Measurement Unit
    - Gyro & Accelerometers
  - Coarse Sun Sensors for Omni coverage
  - Reaction wheels (ARDV free flight only)
  - *ACS receives data from ARPOD suite via* I/F with VPU



Flagship Technology Demonstrations
ARDV Back-up Info

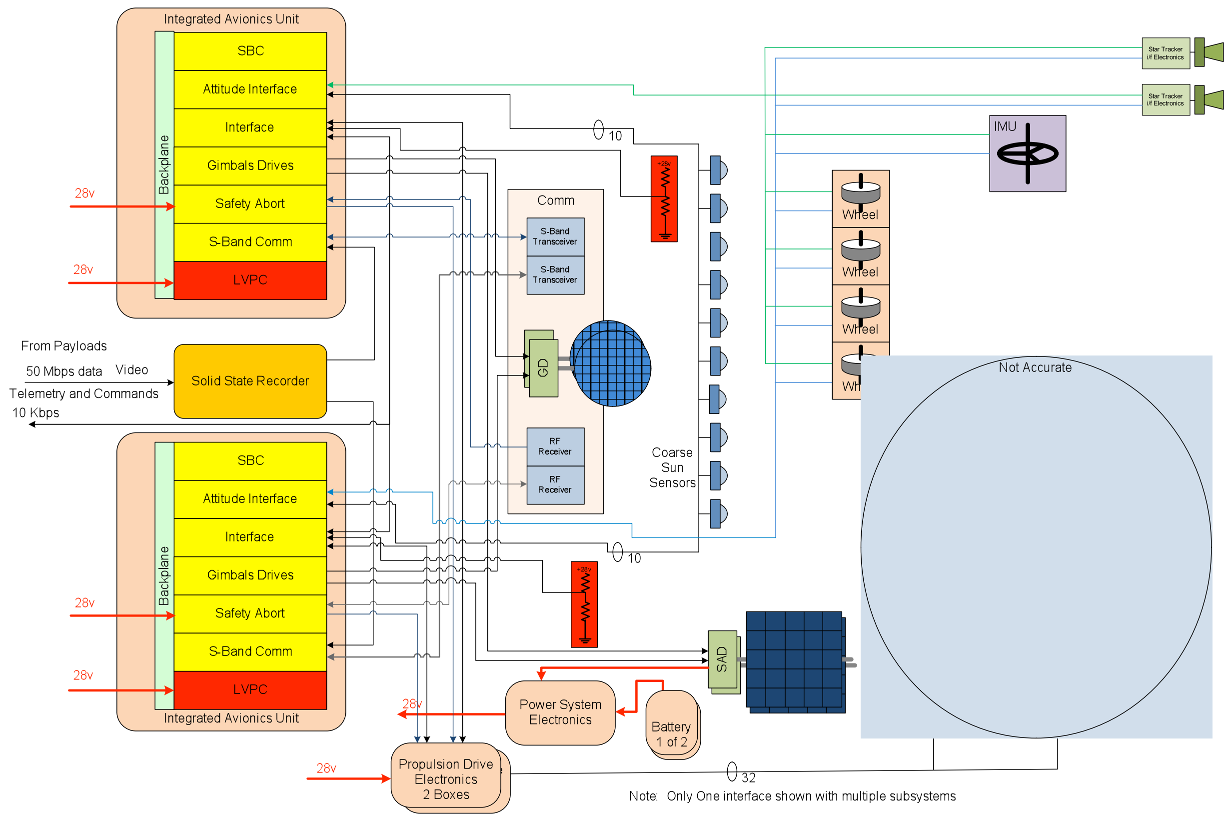
ARDV Design Summary continued

- **Power System:** Battery Dominated DET design based on LRO ~2.0 kW bus at 28V
  - Two Li-Ion Batteries
  - Internally Redundant Power Control Electronics
  - Articulated Solar Arrays (11.4 m^2)



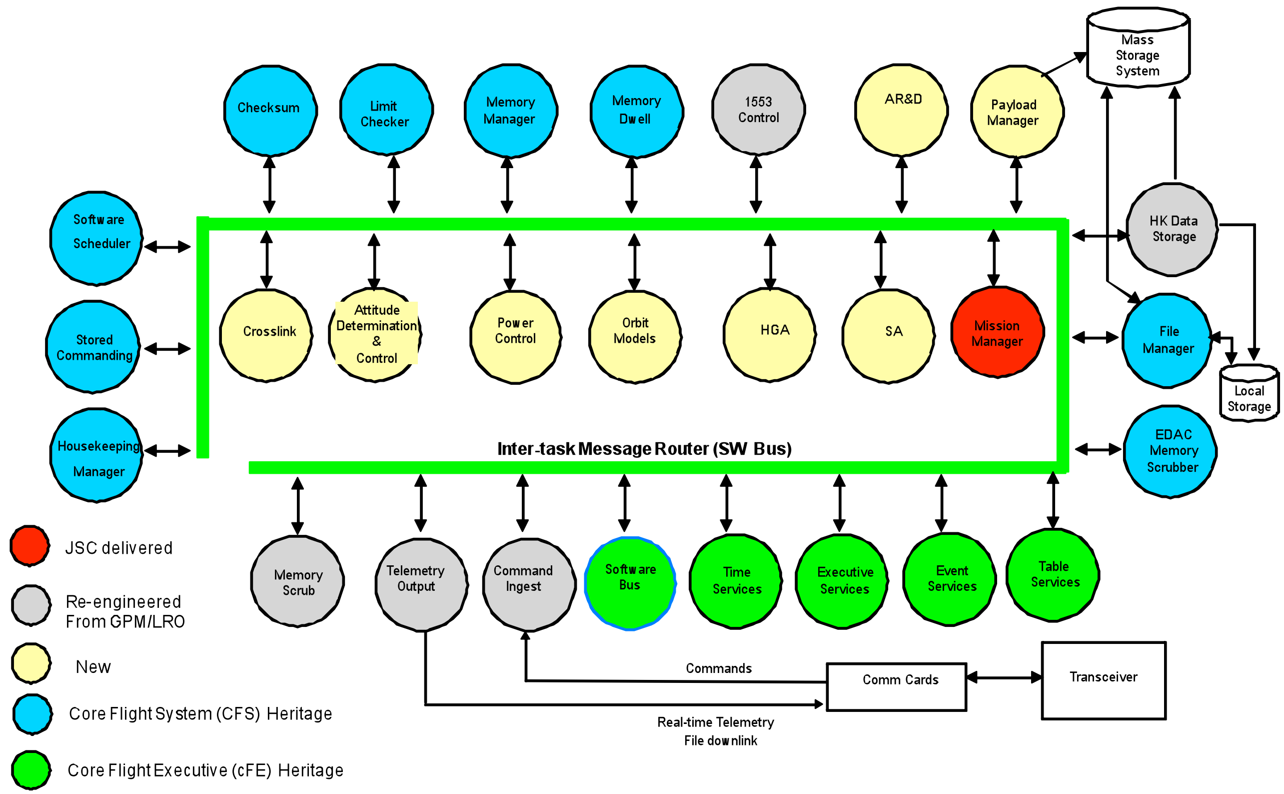
ARDV Design Summary continued

- **Avionics System:** Redundant Heritage Design
  - Pair of 6U BAE750 SBC based Command Data Handling (C&DH) boxes, similar to SDO/LRO designs.
    - » 250 Gb of SSR memory
    - » MIL-STD-1553 bus
    - » High speed LVDS (RS422) interface to VPU for ARPOD data.
  - Propulsion Driver Electronics (PDE) based on LRO
  - *Additional independent ISS proximity FS control unit tentatively required (similar to HTV)*



ARDV Design Summary continued

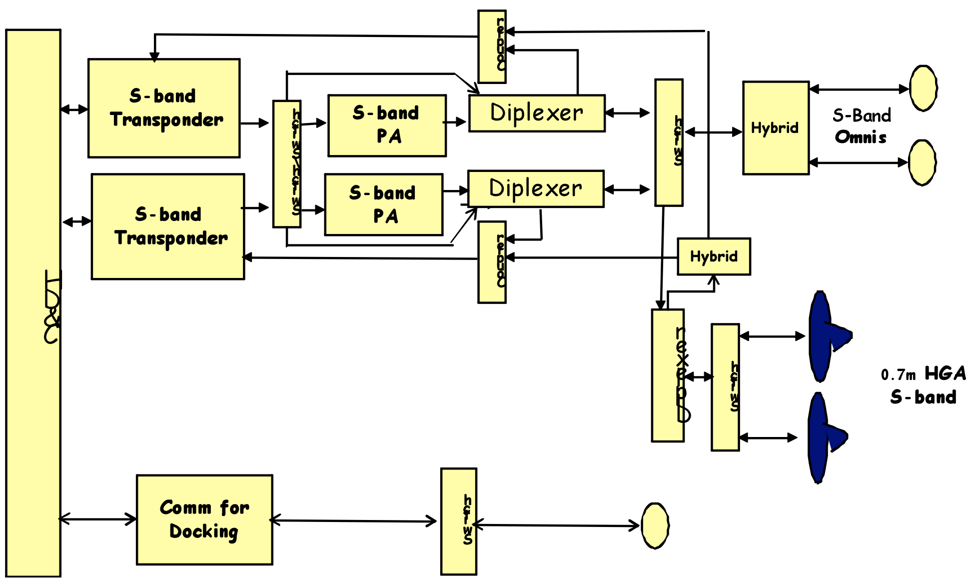
- **Flight Software:** Built around GSFC Core Flight Executive (cFE)/Core Flight System (CFS)
  - COP-1 protocol commanding
  - Incorporates Mission Manager as script interpreter
  - *Possible candidate mission for implementing ARINC 653 standards which may reduce FT/FS burden on H/W.*



ARDV Design Summary continued

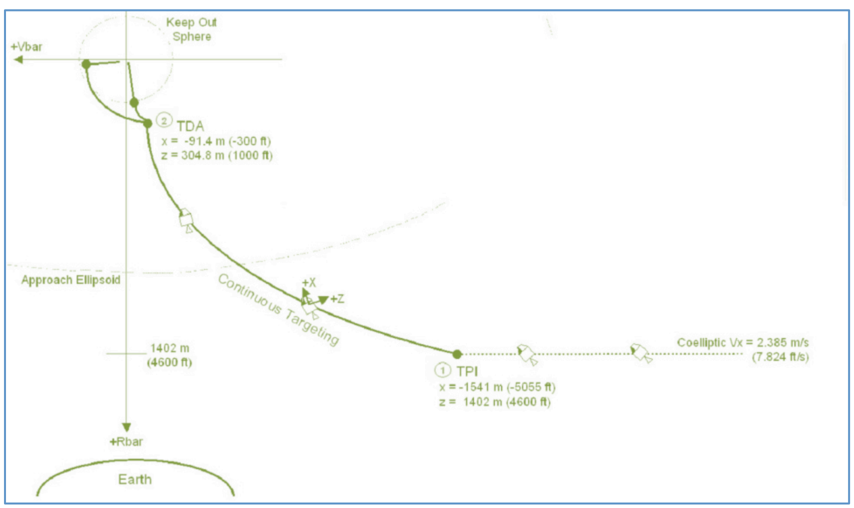
- **Primary Communication System:** S-Band TT&C system with nominal ground link via TDRSS. GN and DSN provide back-up.
  - Dual 0.7m articulated HGAs plus omni antennas
  - Dual 50W amplifiers, can be by-passed for low rate S-band
  - 2 Kps commanding
  - 5.4 Mbps down link to support ARPOD video during near-field operations

- Separate System required for ISS and inter-vehicle communication/ranging



ARDV Design Summary continued

- **ARPOD System:** Sensor & Processing suite consists of:
  - Vision Navigation Sensor (VNS)
  - Active Pixel Star Tracker
  - Docking Camera
  - Inter-vehicle Communication & Range/Range-Rate RF system
  - Natural Feature Image Recognition System (NFIR)- software which uses cameras and other image data
  - Vision Processing Unit (VPU) - process image data and integrated suite data for comm to C&DH
  - *Must be redundant for critical/FS ops, trade between functional redundancy and H/W redundancy*



Strawman AR&D Sensor Suite (from planned DTO)

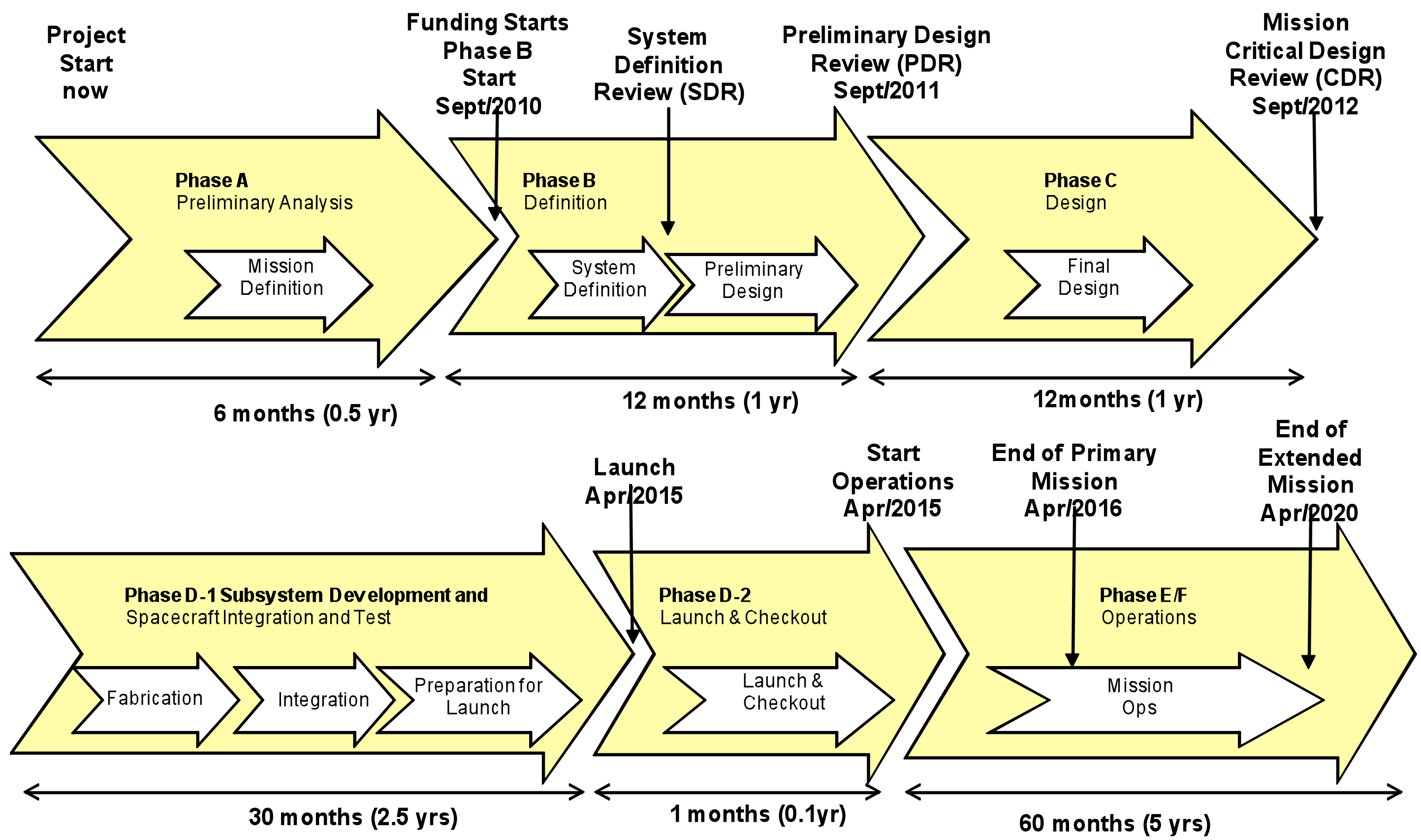
Sensor	Technology Type	Data Type
Star Tracker (x2)	Optical **First Ball Active Pixel Sensor (APS) Tracker**	Bearing
RF Communications (x1)	RF Signal **(Not being tested on DTO)**	Range Range rate
VNS component: TOF LIDAR (x1)	Flash LIDAR	Range Range rate Bearing
VNS component: Spot Pose (x1)	Laser illumination + Optical	6DOF relative position and attitude
Centerline/Docking Camera (x1)	Optical	Lateral cues

Flagship Technology Demonstrations

ARDV Back-up Info

Notional ARDV Development Schedule Roll-Up

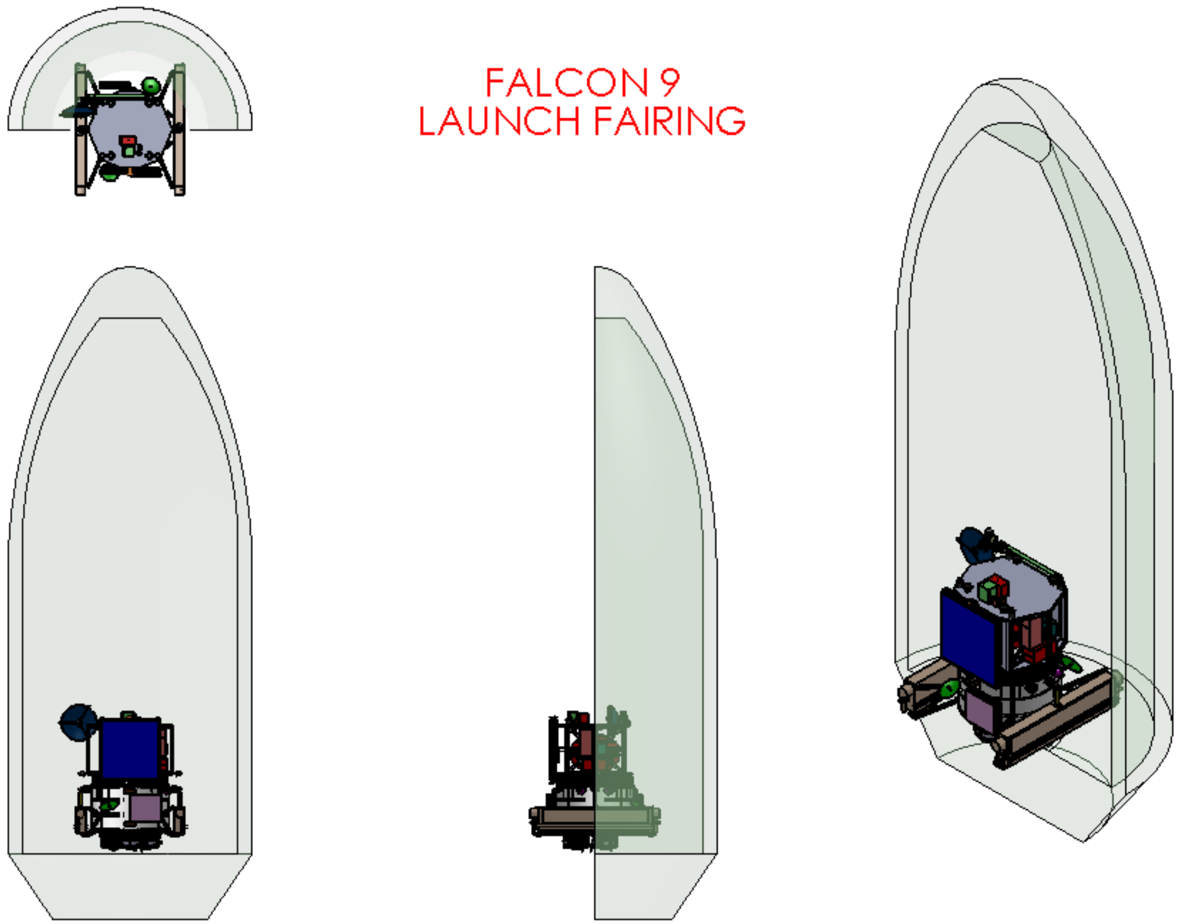
- Assumes in-house GSFC/JSC first build
- Paced/optimized for FTD-2 (Depot) Mission in 2015
- Can be accelerated for earlier launch in 2013 or 2014



FTD ARDV-*Lite* Concept

Used on FTD-1/SEP Mission

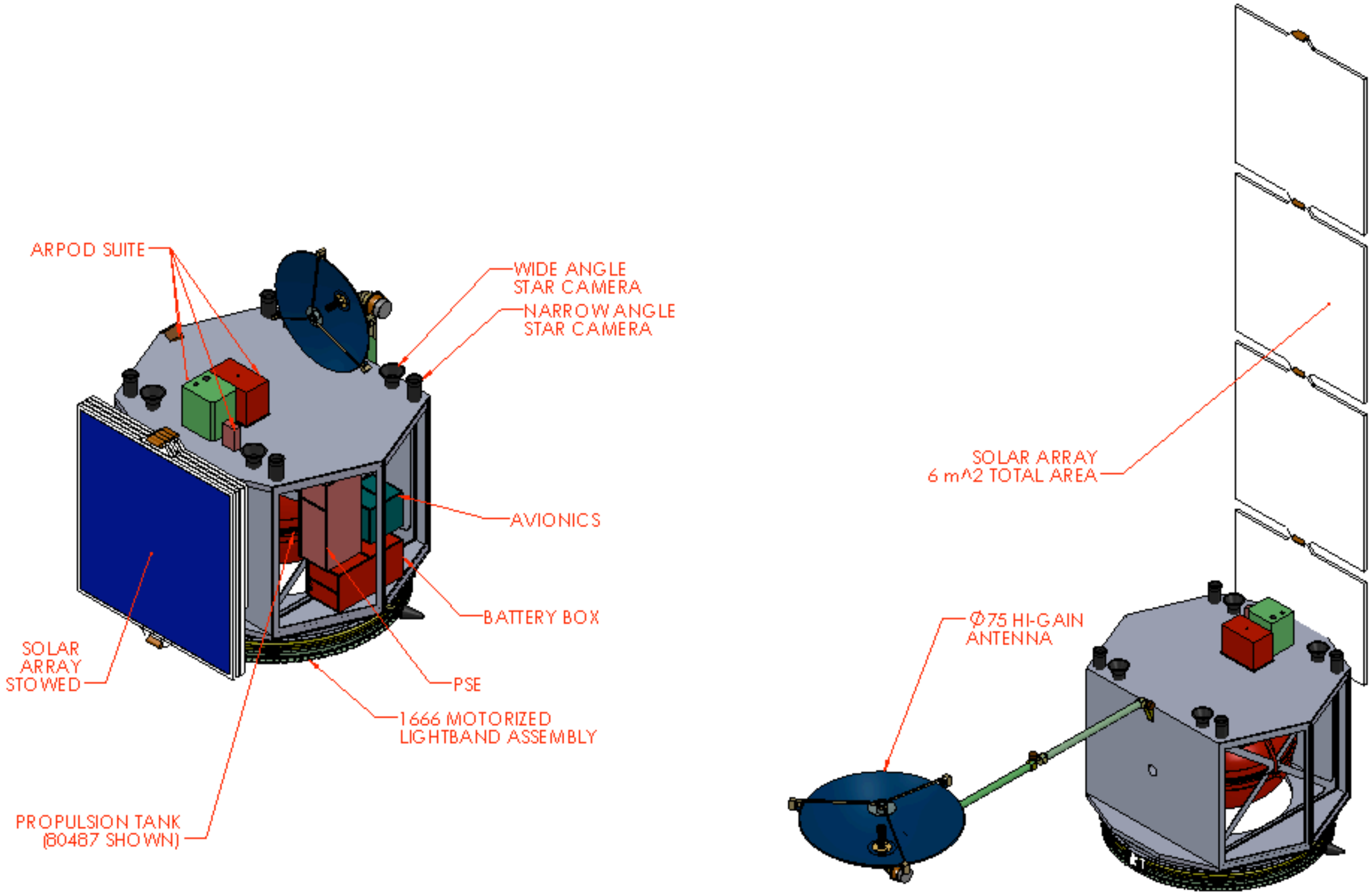
<u>*FTD-1 SEP Vehicle and ARDV-Lite Stowed in ELV Fairing*</u>



FTD ARDV-*Lite* Concept

Used on FTD-1/SEP Mission

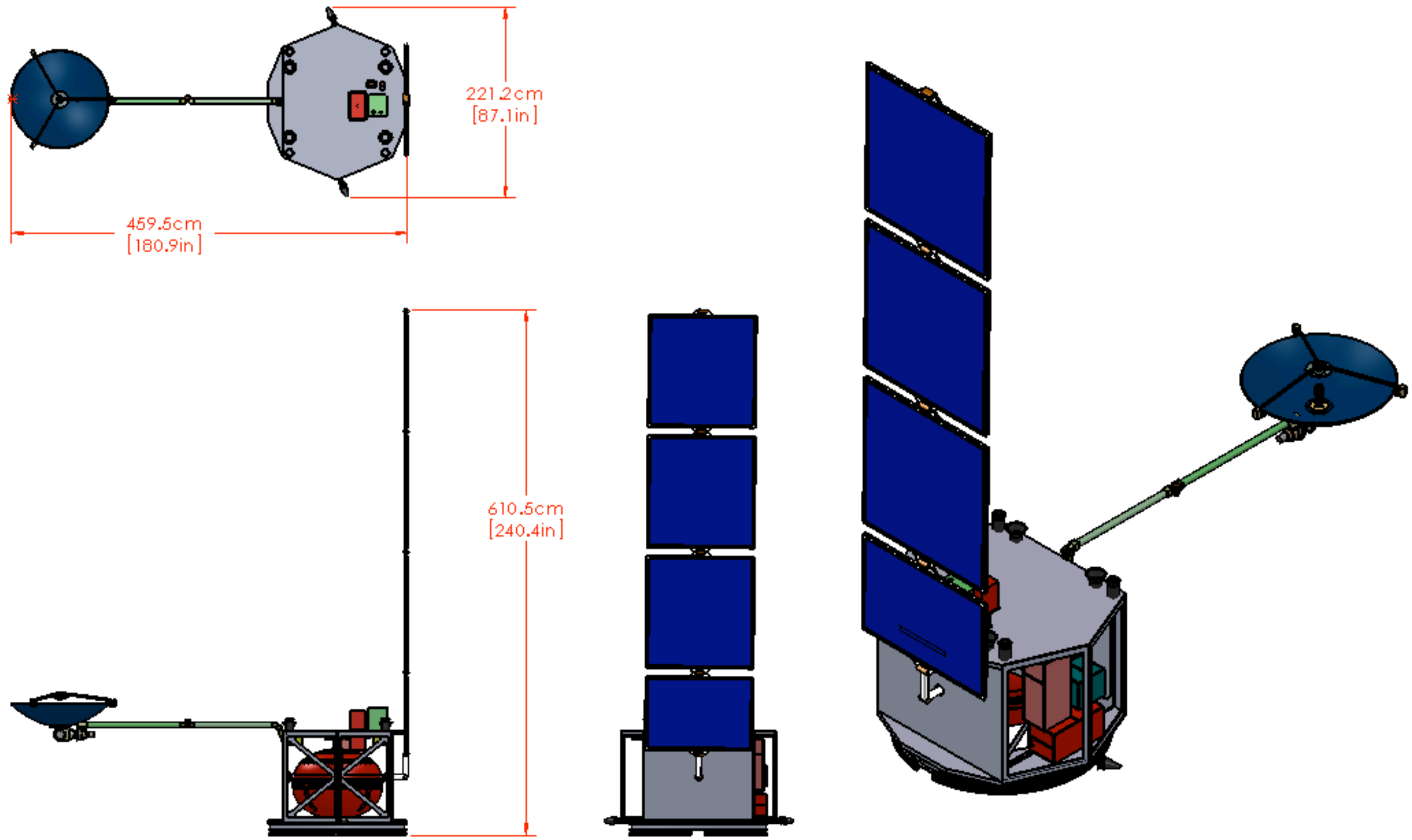
ARDV-Lite Stowed and Deployed Configurations



FTD ARDV-*Lite* Concept

Used on FTD-1/SEP Mission

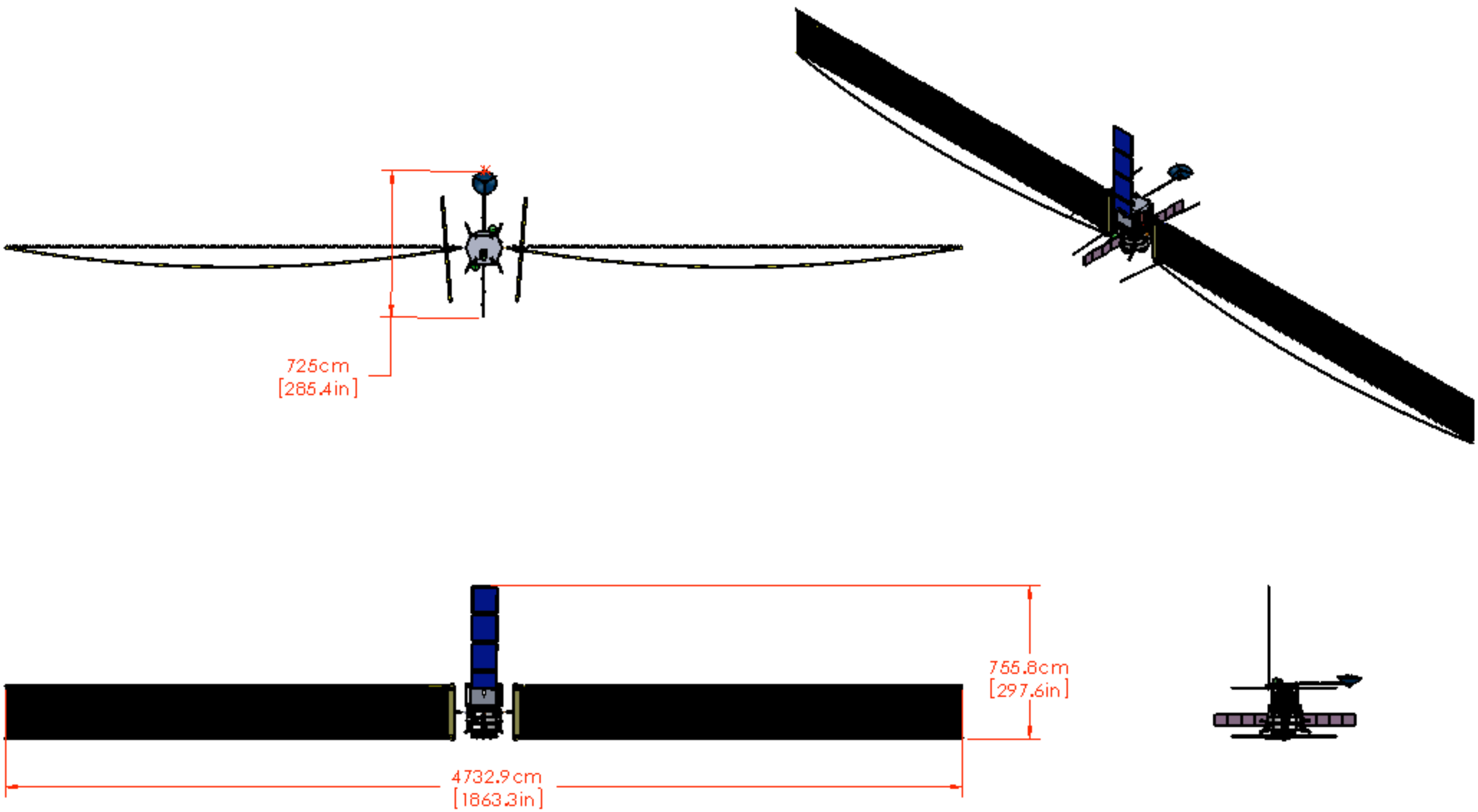
ARDV-Lite Deployed Configuration



FTD ARDV-*Lite* Concept

Used on FTD-1/SEP Mission

FTD-1 SEP Vehicle with ARDV-Lite attached for transit



FTD ARDV-*Lite* Concept
Used on FTD-1/SEP Mission

Preliminary MEL Summary for *ARDV-Lite*

Item	LRO	LRO Percentages	ARDV CBE [kg]	ARDV Percentages	Composite Mass Growth Allow. [%]	Max Expected Mass [kg]
Spacecraft	1015		725			869
ACS	61	6.0%	38	5%	10%	41
C&DH	23	2.3%	46	6%	10%	51
Harness	71	7.0%	71	10%	30%	92
Power	170	16.7%	94	13%	20%	113
RF Comm	73	7.2%	25	3%	20%	30
Structure and Mechanisms	317	31.2%	278	38%	20%	334
Thermal	86	8.5%	44	6%	30%	57
Dry Propulsion	121	11.9%	79	11%	15%	91
AR&D and secondary payload	93	9.2%	49	7%	20%	59
ILIDS Docking				0%	20%	0
Satellite *(S/C + Probe)* Dry Mass	1015		725			869
Additional Payload						0
Propellant Mass for delta V	897		121		1%	123
Satellite Wet Mass	1912		846			991